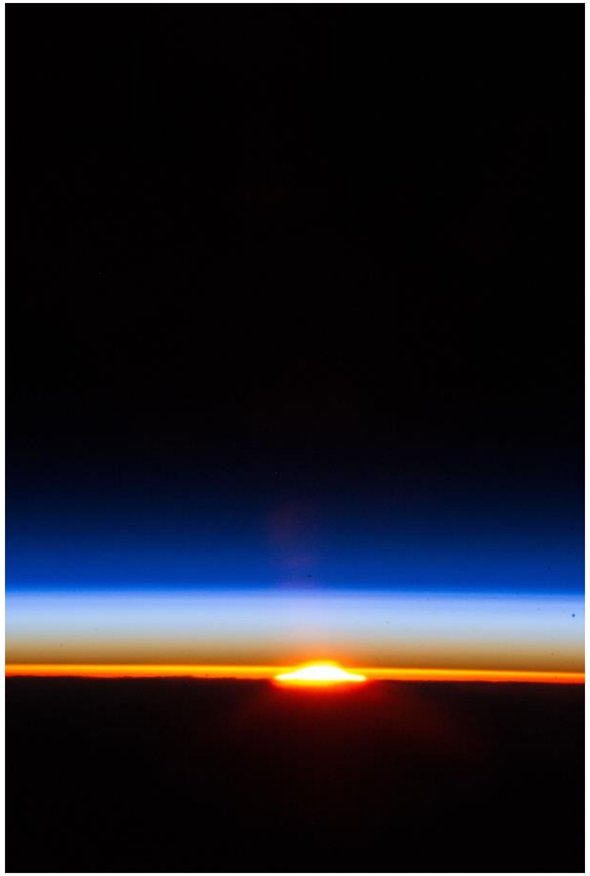
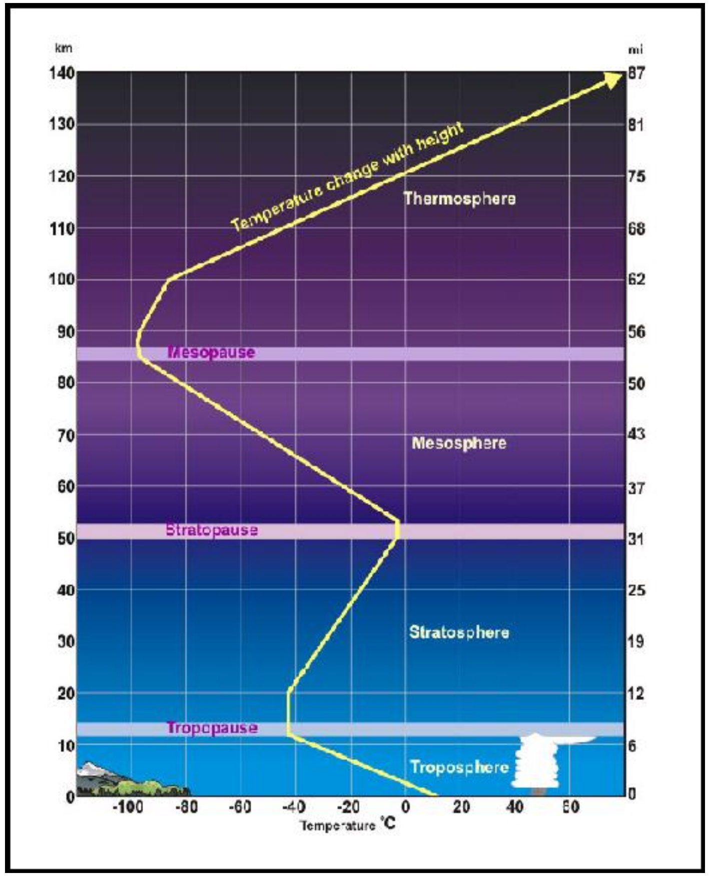
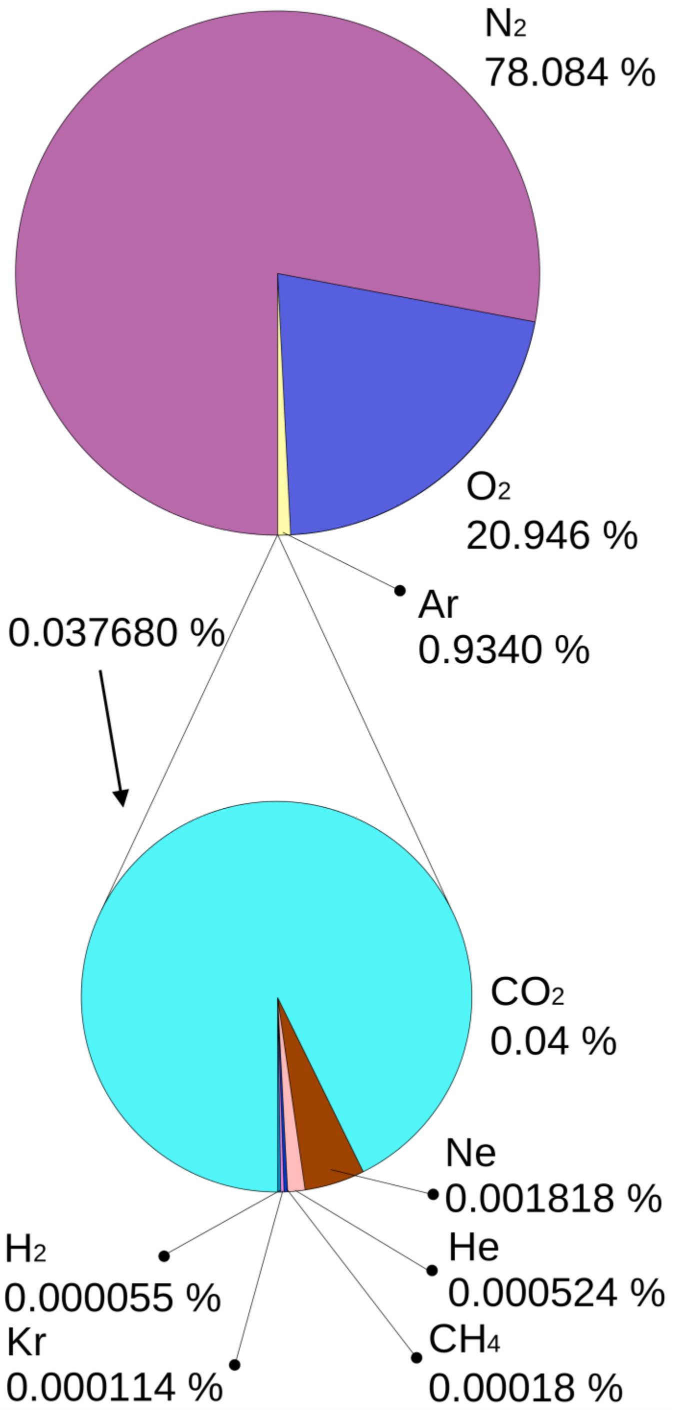
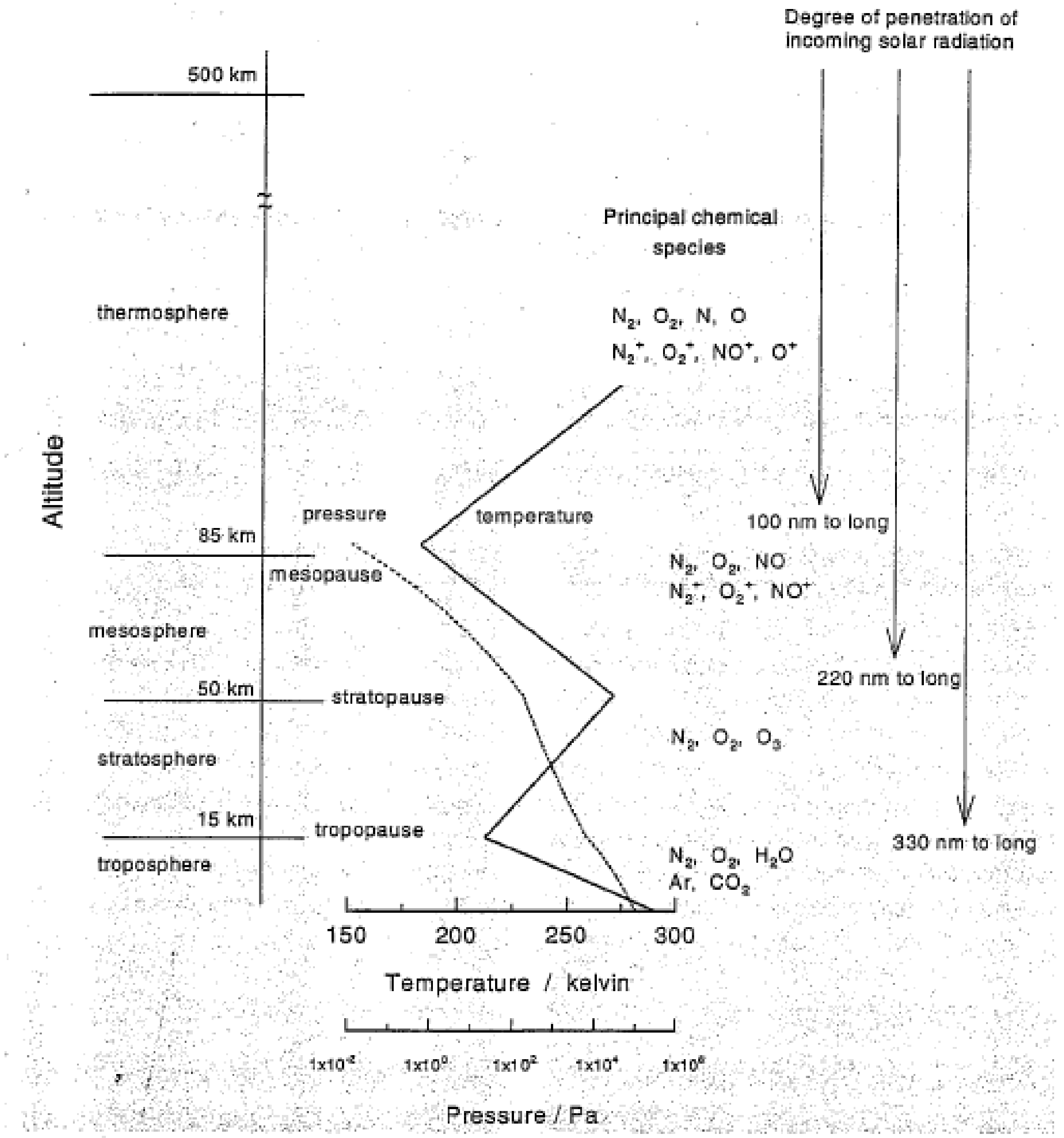
Structure and Composition of Earth's Atmosphere






N2
78.084 %
O2
20.946 %
Ar
0.9340 %
0.037680 %
CO2
0.04 %
Ne
0.001818 %
He
0.000524 %
CH4
0.00018 %
H2
0.000055 %
Kr
0.000114 %


Degree of penetration of incoming solar radiation
500 km
Principal chemical species
thermosphere
N_2, O_2, N, O
N_2^+, O_2^+, NO^+, O^+
Altitude
pressure
temperature
100 nm to long
85 km
mesopause
N_2, O_2, NO
N_2^+, O_2^+, NO^+
mesosphere
220 nm to long
50 km
stratopause
stratosphere
N_2, O_2, O_3
15 km
tropopause
330 nm to long
troposphere
N_2, O_2, H_2O
Ar, CO_2
150
200
250
300
Temperature / kelvin
1×10^{-2}
1×10^{0}
1×10^{2}
1×10^{4}
1×10^{6}
Pressure / Pa

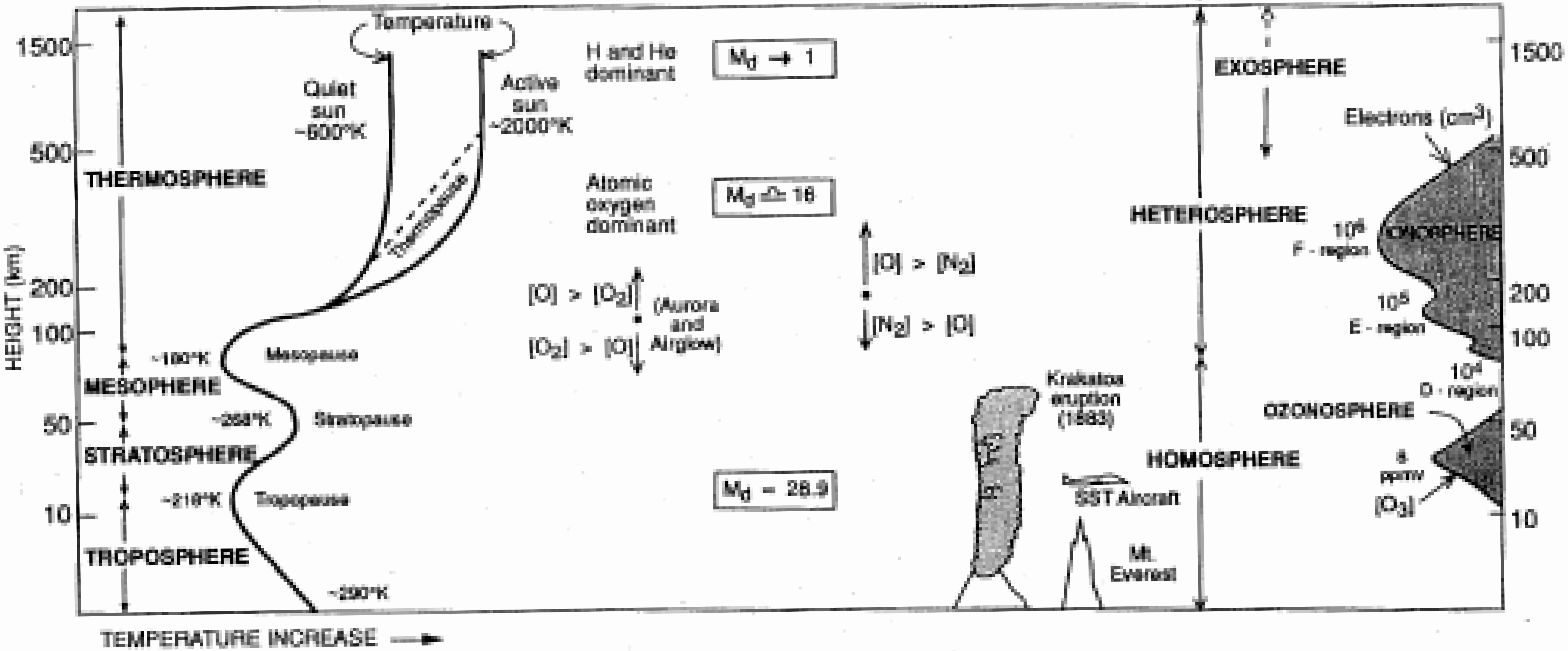


Figure 3.1. Two ways of dividing the atmosphere: by temperature structure (left side) and by composition (right side). The change in the apparent molecular weight of air (M_d) due to the changing composition of the atmosphere with height is shown in the center.

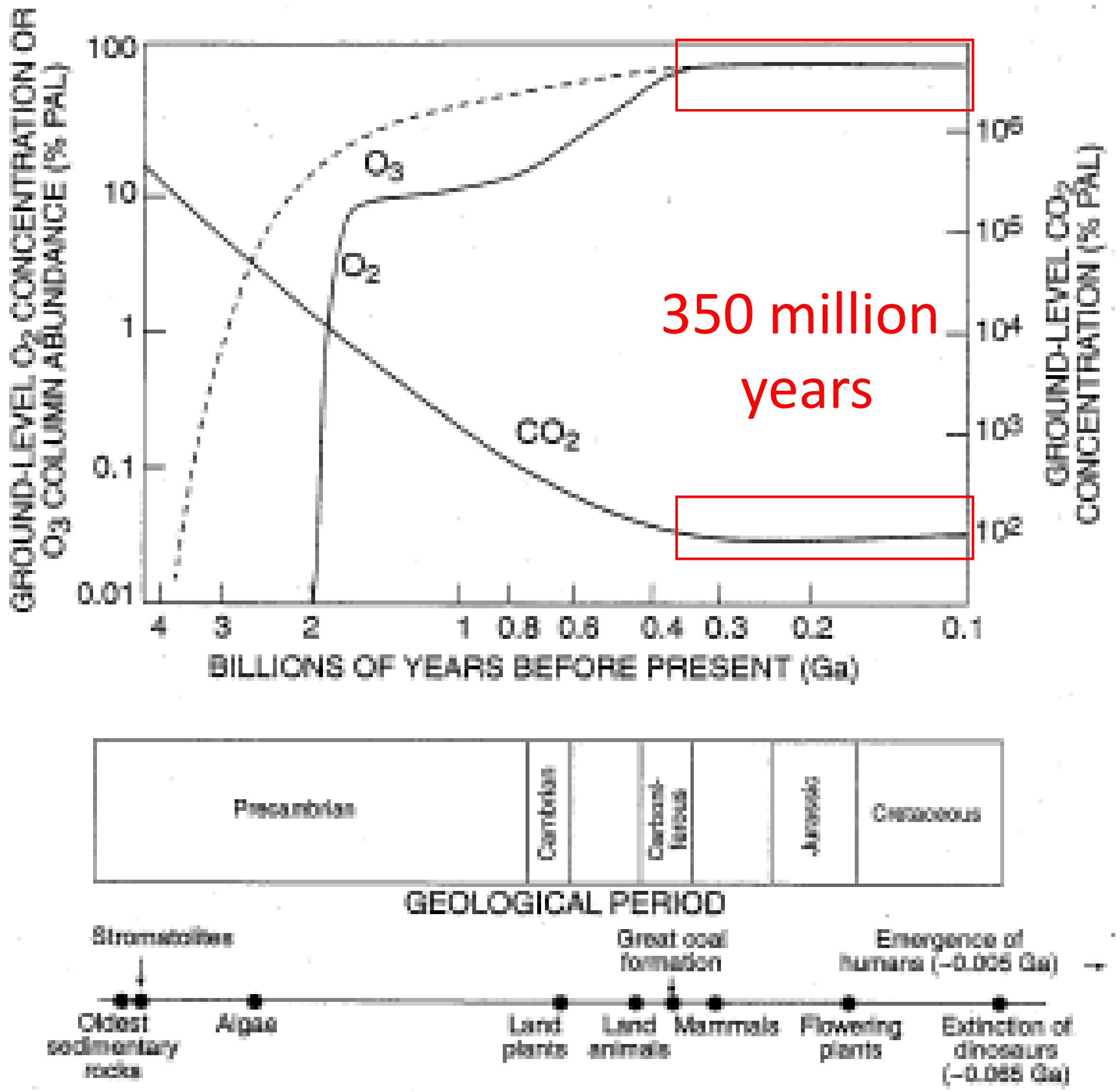


Figure 1.2. Schematic diagram showing predictions of the evolution of oxygen, ozone and carbon dioxide to present atmospheric levels (PAL). [After R. P. Wayne, *Chemistry of Atmospheres*, Oxford University Press, p. 404 (1991) by permission of Oxford University Press; and, J. F. Kasting, personal communication (1999).]

Biological Processes

$$H_2O + CO_2 \rightarrow O_2 + \{CH_2O\}$$

hv (sunlight)

← Respiration

← Combustion

Table 1.1. *Composition of dry unpolluted air by volume*

Nitrogen	78.084%
Oxygen	20.946%
Argon	0.934%
Carbon dioxide	360 ppm (variable)
Neon	18.18 ppm
Helium	5.24 ppm
Methane	1.6 ppm
Krypton	1.14 ppm
Hydrogen	0.5 ppm
Nitrous Oxide	0.3 ppm
Xenon	0.087 ppm

Table 1.4. *Size and general mixing of various reservoirs. Plants, animals and organic matter are included in the biosphere, but not coal or sedimentary carbon.*

	mass (kg)	mixing time (a)
Biosphere	4.2×10^{15}	60
Atmosphere	5.2×10^{18}	0.2
Hydrosphere	1.4×10^{21}	1600
Crust	2.4×10^{22}	$> 3 \times 10^{7}$
Mantle	4.0×10^{24}	$> 10^{8}$
Core	1.9×10^{24}	

~ 60-80 days

Table 1.5. *Standard properties of the atmosphere at sea level*

Density	$1.2250014\ \mathrm{kg\ m^{-3}}$
Gravitational acceleration (g)	$9.80665\ \mathrm{m\ s^{-2}}$
Kinematic viscosity	$1.4607 \times 10^{-5}\ \mathrm{m^2\ s^{-1}}$
Mean free path	$6.632 \times 10^{-8}\ \mathrm{m}$
Molecular weight (M_m)	28.966
Number density (n)	$2.5476 \times 10^{19}\ \mathrm{cm^{-3}}$
Pressure (p)	101325 Pa
Scale height (H)	8434 m

66 nm →

$$P_H = P^o e^{-1} = 1/e\ P^o = 0.37\ P^o$$

Table 2.1. *Residence times of some atmospheric gases*[a] *(in many cases only very rough estimates are possible)*

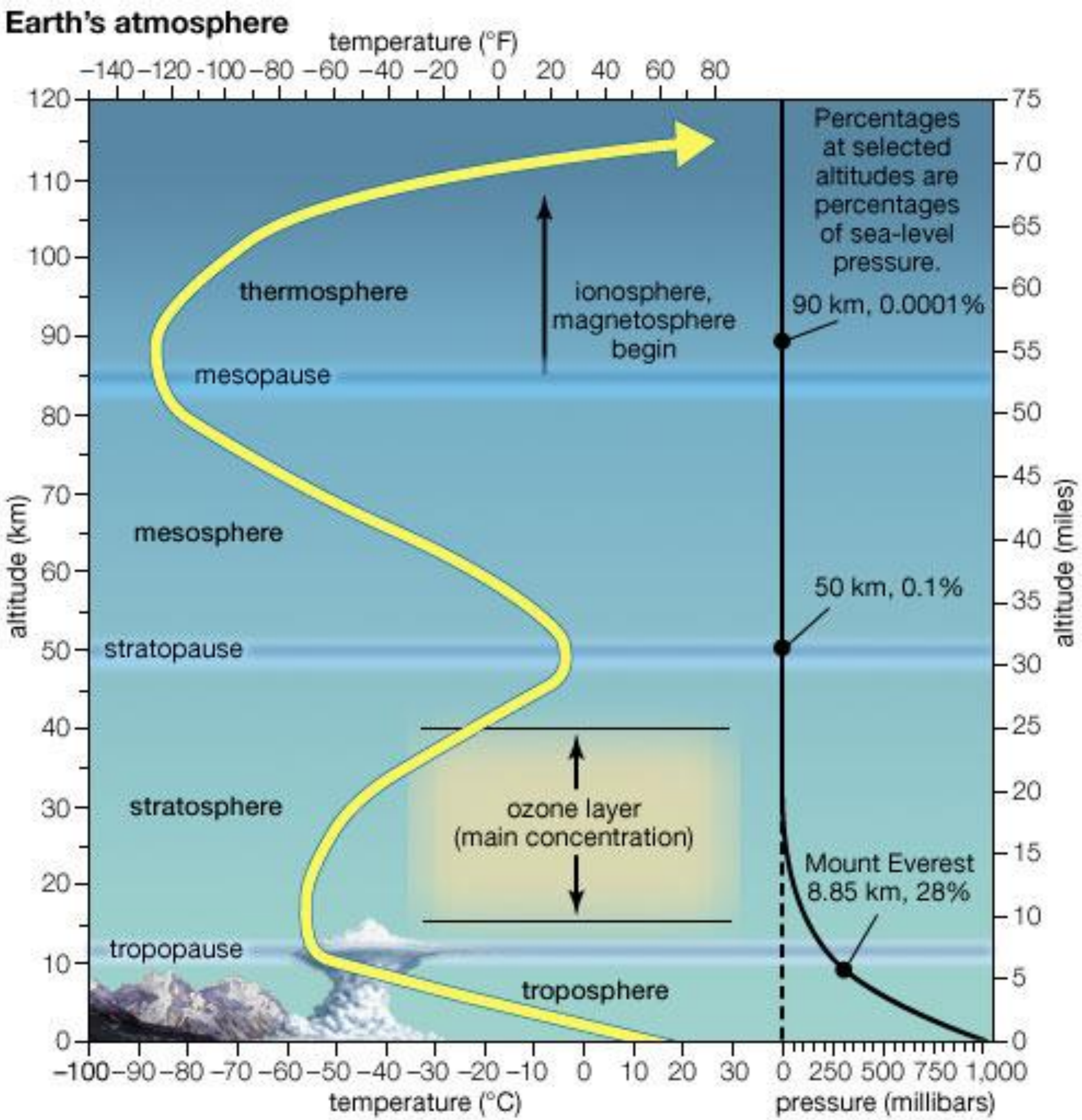
Gas	Residence Time
Nitrogen (N_2)	1.6×10^7 a
Helium (He)	10^6 a
Oxygen (O_2)	3,000–10,000 a
Carbon dioxide (CO_2)	3–4 a
Nitrous oxide (N_2O)	150 a
Methane (CH_4)	9 a
CFC-12 (CF_2Cl_2)	>80 a
CFC-11 ($CFCl_3$)	~80 a
Hydrogen (H_2)	4–8 a
Methyl chloride (CH_3Cl)	2–3 a
Carbonyl sulfide (COS)	~2 a
Ozone (O_3)	100 days
Carbon disulfide (CS_2)	40 days
Carbon monoxide (CO)	~60 days
Water vapor[b]	~10 days
Formaldehyde (CH_2O)	5–10 days
Sulfur dioxide (SO_2)	1 day
Ammonia + Ammonium ($NH_3 + NH_4^+$)	2–10 days
Nitrogen dioxide (NO_2)	0.5–2 days
Nitrogen oxide (NO)	0.5–2 days
Hydrogen chloride (HCl)	4 days
Hydrogen sulfide (H_2S)	1–5 days
Hydrogen peroxide (H_2O_2)	1 day
Dimethyl sulfide (CH_3SCH_3)	0.7 days

[a] The residence time (or lifetime) is defined as the amount of the chemical in the atmosphere divided by the rate at which the chemical is removed from the atmosphere. This time scale characterizes the rate of adjustment of the atmospheric concentration of the chemical if the emission rate is changed suddenly.

[b] The residence time of liquid water in clouds is ~6 h.

Chemically ‘inert’

Chemically ‘reactive’



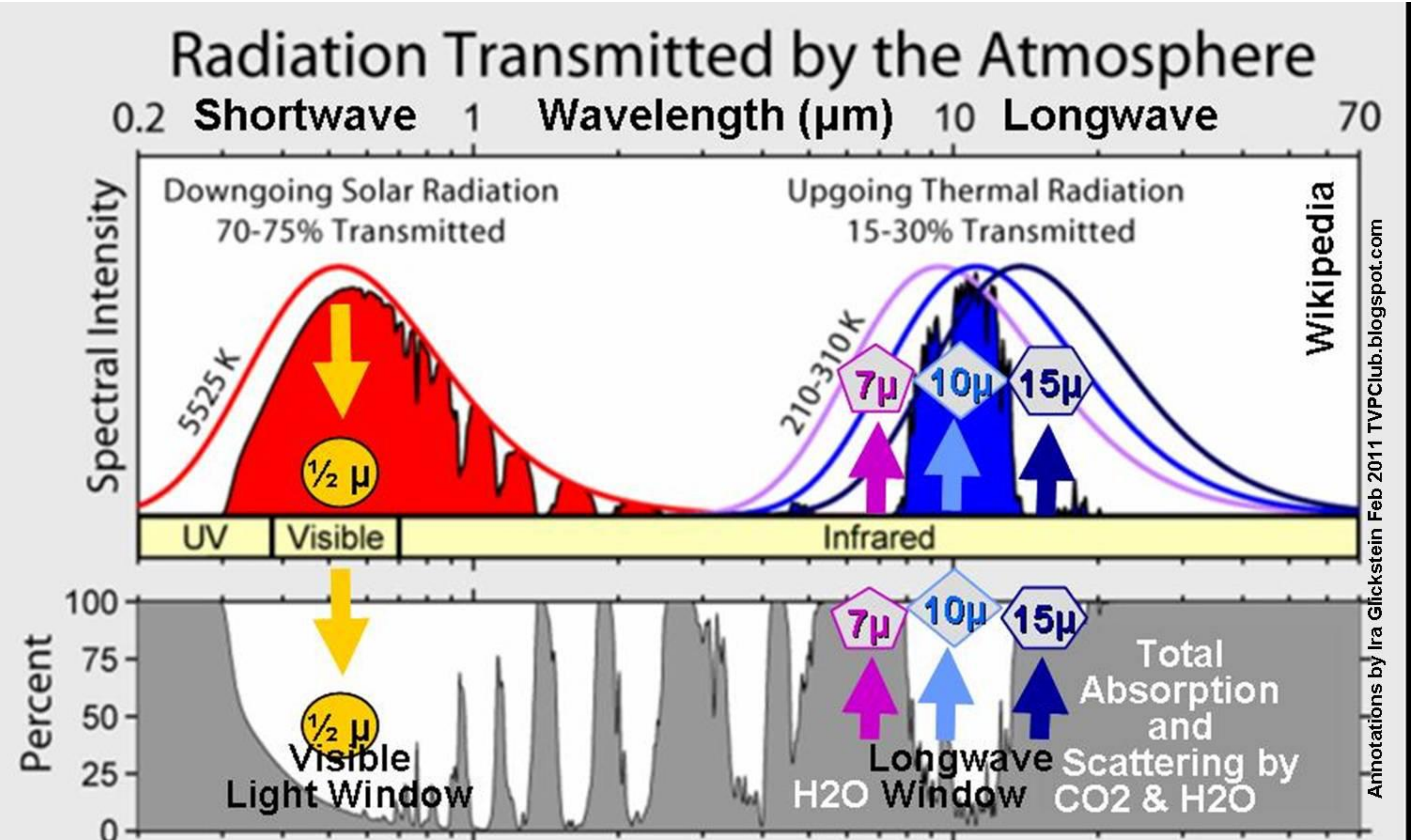
Thermal Structure

<u>Radiative Energy Balance</u>

Energy in (absorbed from Sun) =
Energy out (emitted by Earth)

Blackbody radiation depends only on temperature of emitter

Sun ~ 6000 K
Earth ~ 255 K



Radiation Transmitted by the Atmosphere
0.2 Shortwave 1 Wavelength (μm) 10 Longwave 70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
Wikipedia
5525 K
210-310 K
½ μ
7μ
10μ
15μ
UV
Visible
Infrared
Percent
100
75
50
25
0
Visible
Light Window
Longwave
H2O Window
Total
Absorption
and
Scattering by
CO2 & H2O
Annotations by Ira Glickstein Feb 2011 TVPClub.blogspot.com

Fig. 1.2. A comparison between (*a*) the electromagnetic spectrum for black bodies at 6000 and 255 K and (*b*) the absorption spectrum of gases in the Earth's atmosphere. Note that the atmosphere is practically transparent to black body radiation emitted at temperatures typical of the sun.